PRODUCT MANAGER C4ISR ON-THE-MOVE EXPERIMENTATION

LTC William Utroska, Product Manager C4ISR On-The-Move
Russell Langan, Deputy Product Manager C4ISR On-The-Move
Michael Amabile, Senior Systems Engineer, Product Manager C4ISR On-The-Move

Introduction

Product Manager C4ISR On-The-Move (PM C4ISR OTM) provides a relevant operational field experimentation venue for the purpose of assessing emerging technologies in a System-of-Systems (SoS) environment. Its charter includes the mitigation of risk for Future Force technologies and the acceleration of technology insertion into the Current Force to support Army transformation. The PM accomplishes this by integrating maturing tech base systems into a holistic SoS architecture, employing early prototypes of objective systems or surrogate and simulated systems as necessary. Technical experimentation and demonstration is then conducted at the component systems level, at the SoS level via scripted end-to-end operational threads, and through unscripted technical assessments involving Soldier role players. Additionally, the PM develops test methodologies, assessment metrics and automated data collection, reduction and analysis techniques to support this experimentation. PM C4ISR OTM is a Research, Development and Engineering Command (RDECOM) organization within the Communications-Electronics Research, Development and Engineering Center (CERDEC) at Fort Monmouth, NJ.

This paper seeks to describe the facilities, capabilities and process that the PM employs to conduct its experimentation. Following that it reviews recent experimentation activities and their relevance to critical development and acquisition issues and provides selected results emerging from ongoing data analysis.

Facilities & Capabilities

PM C4ISR OTM leverages a significant Army capital investment in a unique C4ISR operational field experimentation venue located at the joint Mega Base centered at Fort Dix, NJ. This venue adds realism and complexity that can not be replicated in a laboratory or through modeling and simulation alone. The PM's facility offers varied and complex terrain for ground maneuvers and communications evaluations, reduced electro magnetic spectrum operating limitations and reduced airspace restrictions for airborne communications relay and ISR evaluations. Additionally, proximity to McGuire Air Force Base and Lakehurst Naval Air Engineering Center provides access to Air Force and Navy runways, hangars, material and personnel.

The heart of PM's facility is the CERDEC Field Experimentation Center, or CFEC. The CFEC provides a central location for systems integration, network configuration, modeling and simulation, and the development of data collection and reduction systems. The CFEC is linked to instrumented field ranges and a fleet of well-equipped, reconfigurable test vehicles. Connections to Fort Monmouth laboratories, as well as to other Army, Joint, industry and academic facilities, enable distributed experimentation. There is also a great investment in human capital: a highly skilled workforce conducts experiments year round to demonstrate and quantify the performance and combat effectiveness of C4ISR systems, system of systems and concepts.

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **01 NOV 2006**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**
4. TITLE AND SUBTITLE **Product Manager C4ISR On-The-Move Experimentation**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **C4ISR On-The-Move**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002075., The original document contains color images.

14. ABSTRACT

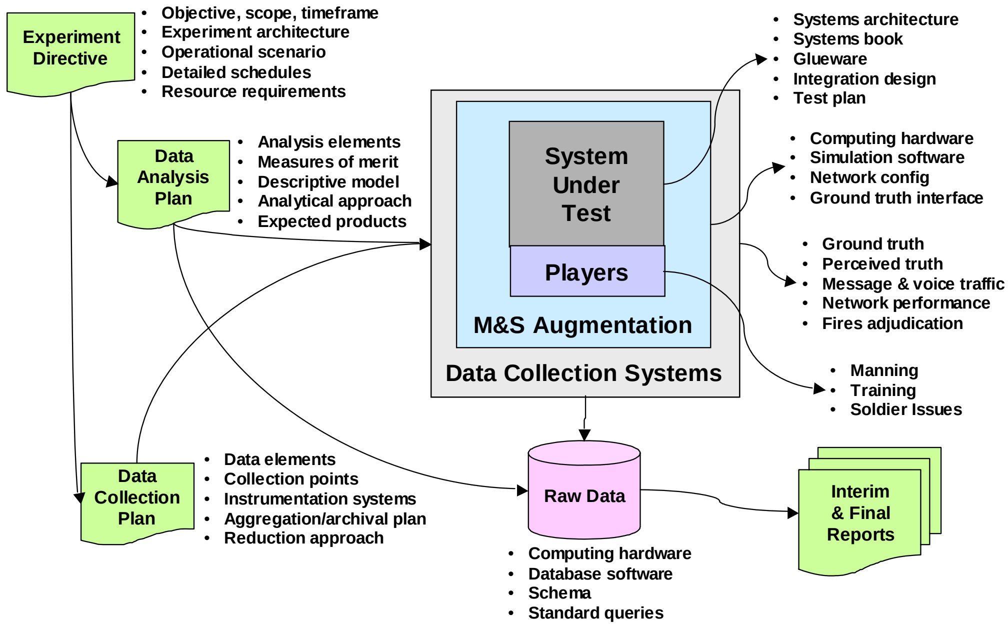
15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**8**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Experimentation Process

The PM employs a structured approach to experimentation, based in part on the Command and Control Research Program's Code of Best Practices for Experimentation and on the Army Concept Development and Experimentation Plan. During its early experimentation activities, the PM developed and refined a conceptual model that defines the term 'experiment'. This model is illustrated below:



This model enumerates the primary components that define the experiment and illustrates their interrelationships. These components include:

- ***Experiment Directive***. The Directive, manifested in the form of a working slide set and formalized in documents, contains the description of what the experiment seeks to accomplish and circumscribes its boundaries. It defines the manner in which the experimental objectives map to stakeholder interests, outlines the manner in which the experiment will be conducted, and details the resources required to conduct the experiment.
- ***Analysis Plan***. The Analysis Plan starts from the experimental objective, and iteratively refines that objective into analysis elements and study issues and then into more quantitative measures of merit. These measures are mapped into generic data elements, which provide the linkage to the more specific Data Collection Plan. Additionally, the Analysis Plan provides the fundamental model that links how the experiment's dependent and independent variables relate to the execution space and how they inform the study issues.
- ***Data Collection Plan***. The Data Collection Plan provides linkage between the generic data elements and the capabilities of the experimental data collection / instrumentation systems. It defines these systems and specifies the points at which the instrumentation 'touches' the tactical system of systems and the manner in which 'human' data collectors will interact with live players. Additionally, it specifies how data will be harvested at the

end of each component activity and how that data will be cataloged, verified and reduced for post-experiment analysis.

- ***System of Systems Specification***. The System of Systems (SoS) is the C4ISR systems architecture that will be provided as equipment to the Player element. The SoS is defined in standard Department of Defense Architecture Framework (DoDAF) products and in a Systems Book that describes each component system. Since the PM is an integration activity for C4ISR products, these products often require varying levels of software 'glue' to enable participation within a holistic system. The SoS Specification includes the architecture products, the Systems Book, a description of the overall integration design and the pre-experiment test plans.
- ***Player Specification***. The Player Specification contains the Operational Architecture for the experimental unit of focus and their surrounding elements. It also includes the Training Plan that describes the manner in which the players will be trained to employ the C4ISR SoS, and provides reference to logistical considerations associated with military personnel.
- ***M&S Augmentation Specification***. In order to better emulate a complete warfighting element and to provide backup for systems in the event weather or safety preclude their play, the System of Systems is 'wrapped' in a modeling and simulation (M&S) environment. The M&S Specification includes the description of how this augmentation is effected and the enumeration of the primary software models employed.
- ***Data Collection / Instrumentation Specification***. The Instrumentation Specification provides specific detail on the design, implementation and integration of the instrumentation system-of-systems. This specification also describes the hardware and software required to house and manage the store of raw experimental data and the suite of tools available to inform analytic measures from the raw data store.
- ***Final Reports***. As formal output, the PM produces a suite of post-experiment reports. The expected contents of this document are provided within the Analysis Plan.

Experiments should not stand alone – due to the scope, complexity and resources required to design and execute true force-on-force experiments, significant economies can be realized by leveraging related work within Army and Joint experimentation venues. As stated by Alberts & Hayes in their recently published work on experimental campaigns:

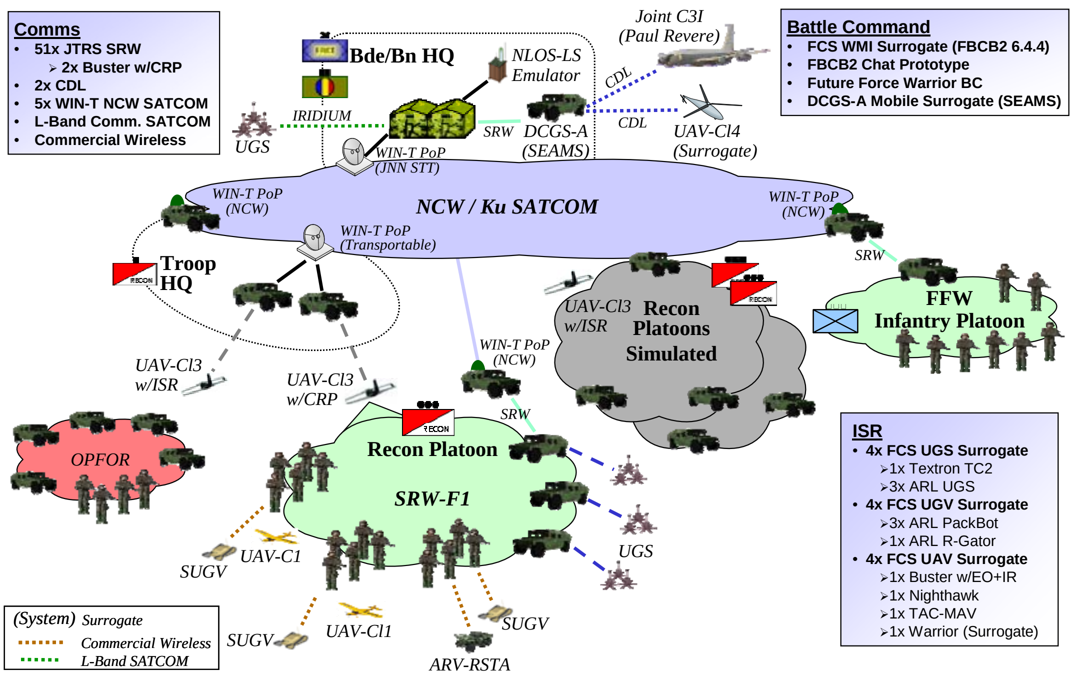
> The value of a given experiment depends upon what is known and what other experiments have been or could be conducted. Hence, the value of a given experiment depends as much (if not more) on the process of knowledge development as the knowledge that it is able to generate by itself…Hence, transformational experiments should be part of a well-designed series of experiments and related activities that we call a campaign. --- *Code of Best Practice – Campaigns of Experimentation (Alberts & Hayes)*

2005/2006 Experimentation Summary

The PM's 2005 and 2006 experimentation activities focused on the assessment of the capability, functionality and performance of Future Combat Systems, FCS Spin Outs and technology insertions into the Current Force. These experiments were based on several TRADOC Unit of Action Maneuver Battle Lab (UAMBL) scenarios, including Omni Fusion. The PM adapted a portion of these scenarios for execution by representations of an FCS Reconnaissance Troop.

The troop's missions consisted of area reconnaissance, as well as surveillance of multiple named areas of interest. For selected missions, the troop was supported by a squad-sized infantry quick reaction force, which conducted a series of coordinated operations. Friendly forces were opposed by an insurgent-style enemy force characterized by small, decentralized cells which behaved like a typical irregular enemy, establishing weapons caches, taking hostages, employing improvised explosive devices and conducting ambushes.

The significance of these experiments was that the Blue Force conducted their missions using Future Force Tactics, Techniques and Procedures, and were equipped with advanced systems and technologies:

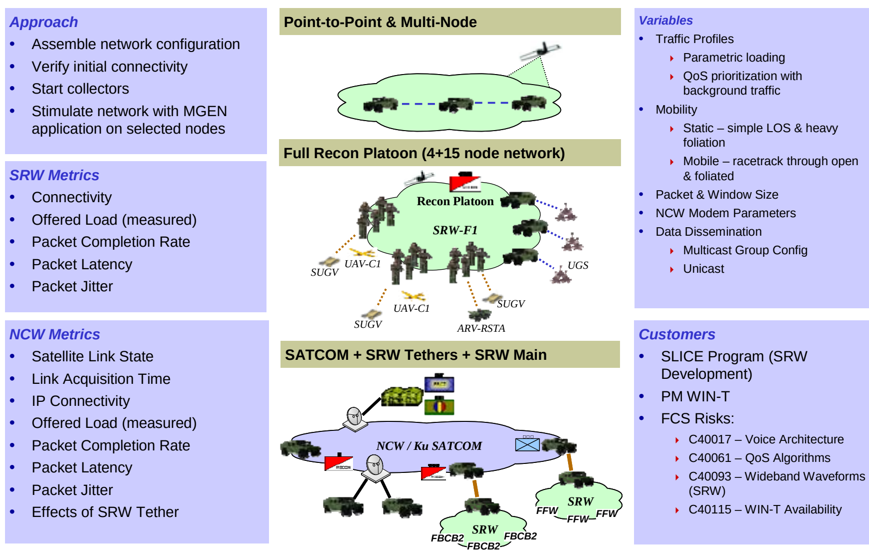


This integrated C4ISR SoS architecture included

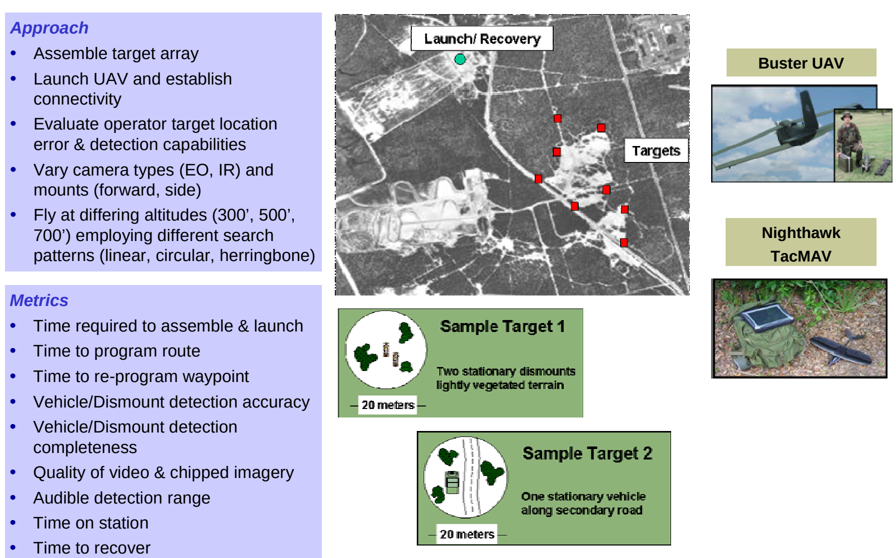
- Ad hoc networking radios running the Soldier Radio Waveform (SRW), providing voice and data communication for both dismounts and vehicles
- Assured connectivity via a tiered communications architecture, consisting of an SRW airborne relay in a small Unmanned Aerial Vehicle (UAV) and multiple SATCOM on-the-move nodes running the WIN-T Network Centric Waveform (NCW)
- Unmanned Aerial Vehicles, Small Unmanned Ground Vehicles and Unattended Ground Sensors, providing intelligence to enhance Situational Awareness
- Battle Command applications to visualize real-time data from friendly forces and fused intelligence products, and provide digital command and control, mission planning and data fusion
- Real-time access to an airborne Joint ISR / Network node, played by the Air Force Paul Revere testbed, providing reachback to theater and national-level intelligence sources
- Interoperability with an adjacent Infantry Quick Reaction Force squad, equipped with Future Force Warrior ensembles

The experiments were conducted in three phases, in which the component systems were initially evaluated relative to established performance standards, followed by evaluations of specifically-defined, end-to-end information flows across the aggregate SoS, and concluding with an technical assessment of the performance of the SoS while employed by live soldiers in an operational environment. This process sought to inform a three-step analysis process linking technical metrics, such as the target location error of a sensor platform, the aggregate completion rate of the radio network and the observed flow of messages within the application layer, and operational metrics, such as loss ratios and mission accomplishment measures, via a set of effectiveness metrics involving the measurement of information quality and warfighter situational awareness.

Two examples of typical component evaluations are provided below. The first, a transport layer evaluation, was focused on the quantification of the performance of the SRW and NCW networks within the overall SoS architecture. Several network configurations of increasing complexity were subjected to parametric loading conditions and the tiered communications architecture was tested to assess the performance of SRW airborne relays for intranet beyond line of sight range extension and WIN-T PoP for internet beyond line of sight range extension for reach and reach-back:

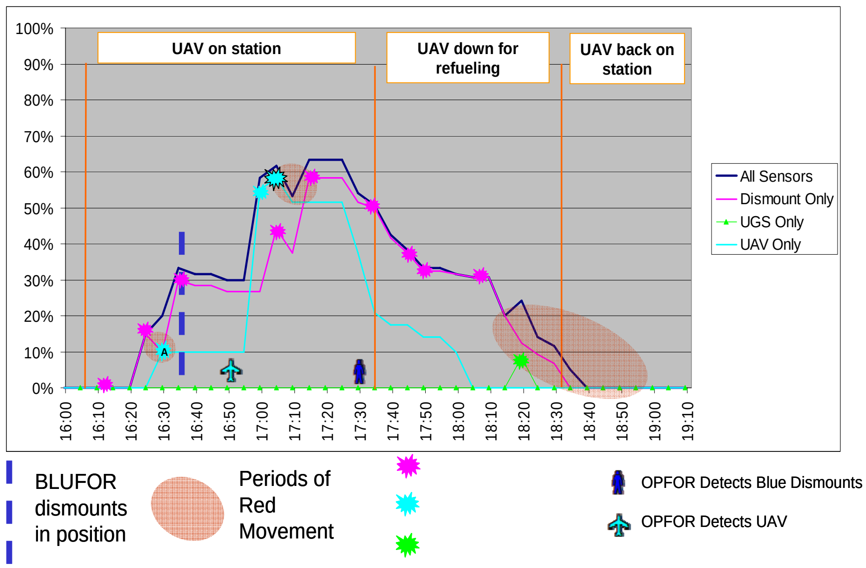


Likewise, a series of unmanned and unattended ground and aerial systems were evaluated. The graphic below summarizes the evaluation plan for small UAV's employed as lower-echelon ISR assets. Specific focus areas included the assessment of Target Location Error (TLE), Probability of Detection (Pd), ease of employment and audible detectability.



Following the component evaluations, a series of application and operational thread experiments were conducted to evaluate the ability of the SoS to deliver information and perform critical tasks. Specific metrics included the measurement of observed offered load, message completion rate, and end-to-end latency.

Through its experimentation and follow-on analysis, the PM also seeks to develop novel metrics for the evaluation of C4ISR effectiveness. Building on the analytic measures employed during prior experimental and analytic venues, the PM has developed a suite of tools focused on a metric termed System Knowledge (SK). SK seeks to capture the quality of information within the system regardless of whether or not that information has been exploited by a decision maker. This metric can reveal the difference in the quality of information across different missions or within a particular mission as different sensors are brought to bear. An example is shown below, where the Y-axis spans a range of 0 to 100%; a value of 100% implies that the information available to the experimental force at that point in time contains targetable information about every enemy entity, i.e. perfect knowledge. The X-axis indicates the time during the mission. The blue SK curve shows an initial value of 0 at the start of the mission. As the UAV comes on station and begins to produce reports, SK grows; likewise, as the UAV goes off-station for refuel, SK declines as knowledge of the threat becomes stale.



Selected Results Summaries from 2005/2006 Experimentation

One of the critical missions of PM C4ISR OTM is the mitigation of risk for the FCS program. FCS risks are specifically defined and cover numerous technological challenge areas faced by the program. During the 2005 and 2006 experiments, the PM directly impacted two of these risk areas by serving as formal risk reduction steps; the PM also indirectly impacted several others, due to its relationships with FCS Complementary Programs and the C4ISR tech base:

- *C40061 Quality of Service Algorithms*
    - Written in as step C40061-01-020
- *C40284 End-to-End Performance of C4ISR Network*
    - Written in as step C40284-01-20B
- *C40017 Voice Architecture*
    - Informs C40017-01-004 (Derive voice metrics w/data collection)
    - Analog to C40017-01-009 (Update models w/Expt1.1 input)
- *C40115 WIN-T Availability*

- *C40093 Wideband Waveforms: SRW*
  - Informs C40093-01-012 (CERDEC SRW 2.1 TFT)
- *C40253 – QoS in Data Dissemination wrt Ad Hoc Networks*
  - Supports C40253-01-401 (release of SoSCOE 1.5) by providing venue to assess data dissemination functionality in live OTM environment
- *MGV0146: Vehicular Motion Effects*
  - Provides opportunity to observe soldiers in relevant environment performing FCS-like tasks
- *WFS0330: Integrate Dismounted Soldier into FCS (Future Force Warrior)*

Related the FCS risk work described above, the PM also seeks to address relevant questions faced by Current and Future Force leadership. Such key questions include:

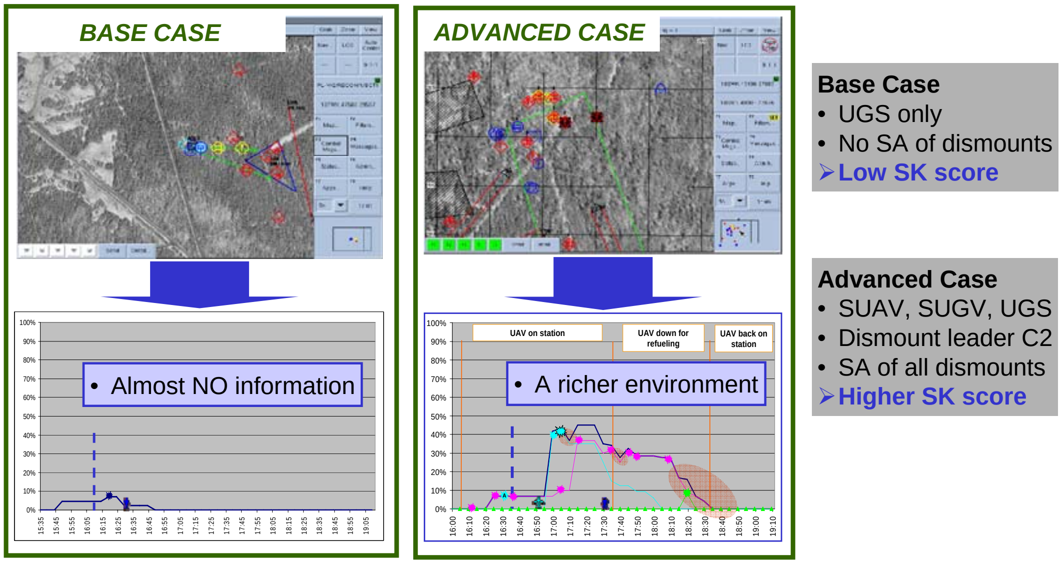
- *What is the effect of Blue situational awareness reporting rate on mission effectiveness and network loading?* In 2005 a sharp distinction was noted between the lack and presence of commander access to real-time position information during mission execution; the 2006 experiment sought to quantify a range of optimal reporting rates that balance the frequency of automated location reporting and network loading.

- *What is the effect of varying intelligence reporting types on commander situational awareness?* In 2005, challenges were experienced in sending imagery from live sensors over the tactical network; the 2006 experiment sought to inform the degree to which imagery was required apart from the sensor ground station and whether terse textual reports could serve equally to increase situational awareness.

- *What is the effect of a dedicated UAV communication relay on network performance and mission effectiveness?* In 2005, the lower tactical network had the benefit of a persistent communications relay effectively as an organic asset. The 2006 experiment was designed to assess the viability of a communications relay within a small UAV and the impact when that UAV becomes unavailable.

- *What is the utility and mix of organic airborne sensors and organic ground sensors?* In 2005, the UAV was observed as the most prolific information generating asset under the imposed conditions. The 2006 experiment focused on varying those conditions and evaluating the impact of each sensor type on overall mission effectiveness.

Looking broader, the PM has also sought to answer the more general question related to the specific impact of a C4ISR SoS on commander situational awareness, decision-making and combat effectiveness. The SK metric described above begins to provide quantitative insight into this global question. In the 2005 experiment, though an insufficient number of runs were conducted to infer statistical significance, it is clear that trends were observed in the capability of the SoS and the value of the SK score. More specifically, less-capable SoS's (e.g., UGS only with no dismounted battle command) yielded lower SK scores and more-capable SoS's (e.g., SUAV and UGS with vehicular and dismount battle command) yielded higher SK scores. This metric provides a promising output to the FCS test community as it grapples with the problem of evaluating a massively complex SoS that is intended to improve lethality and survivability via the information domain. Additionally, through intrusive player surveys designed to elicit self-assessed situational awareness (SA) of the battlespace, clear trends emerge that link higher SK scores with higher warfighter SA. These trends begin to paint a linkage between the SoS performance and observed mission accomplishment measures. In short, data suggests that more capable and information-rich SoS's can impact mission effectiveness in a measurable way.



Observed relationship between more capable configurations and higher SK

Conclusion

PM C4ISR OTM designs experiments to better inform senior Army and Department of Defense (DoD) leaders making critical research, development and acquisition investment decisions. The empirical results and lessons learned from these experiments will inform DoD Program Managers and their industry partners to help mitigate risks and accelerate development for technology transition to the Current, Modular and Future Force.

PM C4ISR On-the-Move is a pilot activity within the RDECOM Campaign of Experimentation and is a key component of Training and Doctrine Command's (TRADOC) FY07 Army Concept Development and Experimentation Plan. It also serves as the Lead Technology Integrator for TRADOC's Air Assault Expeditionary Force experiment series. Going forward, PM C4ISR OTM can provide significant value supporting Future Force development and Current Force transformation by:

- Acting as an experimentation venue to assess maturing technology and concepts
- Assessing Army Technology Objectives (ATO's) products that are on transition paths to FCS and accelerating candidate acquisition or industry technologies
- Maintaining direct relationships with select Complementary Programs which feed FCS
- Maturing data collection, reduction and analysis tools and techniques that support the quantification of C4ISR SoS performance